Shallow Water Array Performance (SWAP): Array Element Localization and Performance Characterization

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LONG TERM GOALS

Acquire and analyze data from the Shallow Water Array Performance (SWAP) program acoustic arrays, deployed about 12 km off the coast of southern Florida and about 14 km from the South Florida Test Facility (SFTF), to evaluate the limits of passive acoustic detection in (high traffic) shallow water environments.

OBJECTIVES

The objectives of this work are to conduct sea trials to acquire and analyze acoustic data recorded from the SWAP array in order to:

1. Determine the locations of the acoustic receive elements, and

2. Perform an initial characterization of array performance.

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14. ABSTRACT
Acquire and analyze data from the Shallow Water Array Performance (SWAP) program acoustic arrays, deployed about 12 km off the coast of southern Florida and about 14 km from the South Florida Test Facility (SFTF), to evaluate the limits of passive acoustic detection in (high traffic) shallow water environments.

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In order to use the SWAP array for studies related to passive sonar detection and localization algorithm development and performance evaluation, it is important to know the relative locations of the acoustic elements within the array. In general, it is desired to localize the elements within approximately 1/20th of the acoustic wavelength which corresponds to a little less than 0.2 m

APPROACH

The SWAP acoustic array consists of four array segments; each segment consists of 125 stations which contain a hydrophone and a 3-axis geophone. The arrays are deployed on the ocean bottom off the coast of southern Florida at a depth of about 250 m. Data from the four array segments is transmitted via four telemetry receivers to a central node and then back to the SFTF via a ~20 km trunk cable. The 125 hydrophones and 3-axis geophones associated with each of the four array segments are sampled simultaneously at a 1 kHz rate, 24 bits / sample. The bandwidth of the hydrophones is approximately 420 Hz (~8 Hz to 428 Hz). Differences in timing for the four telemetry receivers, the four arrays, can be resolved through comparison with GPS PPS (pulse-per-second) timing pulses.

To accomplish the objectives of this task, two at-seat tests were planned for August of 2007; the Array Element Localization (AEL) Test and the Low Level Tow Test (LLTT) [1, 2].

The primary objective of the AEL test was to acquire the data necessary to determine the hydrophone locations for each of the four SWAP array segments. Secondary objectives were to conduct a trial run for the follow-on LLTT to help guide selection of the final run geometries and waveform parameters. In addition, a test was designed to acquire data to support the characterization of geophone performance.

The objectives of the LLTT were to acquire data to support analyses of the minimum detectable level in the region around the SWAP array segments and to estimate propagation loss. The secondary objective of the LLTT was to repeat AEL runs as required.

WORK COMPLETED

The AEL Sea Test was conducted during the period 6-10 August 2007. The second sea test, the LLTT Sea Test was conducted during the period 24-28 August 2007. ARL:UT rented the J15 source and tow body, shown in Fig. 1, from NUWC-USRD, and provided the associated electronics to drive and monitor the projector, including power amplifier, impedance matching network, waveform generator, GPS with PPS (pulse per second output) to synchronize transmits for the AEL runs, monitoring hydrophone and pressure/depth sensor attached to the J15 tow body, and an A2D system to record the projector drive voltage and current and the monitoring hydrophone and pressure sensor outputs.

Figure 1. J15 Source and Tow Body Secured on the R/V Stephan Dive Platform

SFTF arranged for ship services, provided by R/V Stephan operated by Florida Atlantic University, and installed the handling equipment for the projector on the R/V Stephan, including the winch and tow cable. SFTF also installed a Trackpoint system on the R/V Stephan to monitor the range, bearing and depth of the tow body. The Trackpoint beacon transponder was attached to the tow cable ~2 ft above the tow body. The Trackpoint system used a GPS input of own ship latitude/longitude position and converted the Trackpoint range and bearing estimate to a lat/long position of the tow body. SFTF also provided a CBT measuring/recording system to acquire Sound Speed profiles.

An overview of the sea test activities is given below; detailed test plans are provided in [1, 2].

AEL Sea Test, 6-10 August 2007

- 6 August, Monday - Mobilization / Pier-side checkout
- 7 August, Tuesday
  - SFTF complete installation of winch
  - At-sea, checkout projector at depth
  - Completed 2 AEL Legs
- 8 August, Wednesday
  - Problem w/J15 source during testing, replaced soundhead
  - Completed 4 AEL Legs
- 9 August, Thursday
  - Completed “preliminary” LLTT track, Leg 0
- 10 August, Friday
  - Completed 4 Geophone Characterization Test Legs

AEL Sea Test, 24-28 August 2007

- 24 August, Friday - Mobilization / Pier-side checkout
- 25 August, Saturday
  - LLTT Leg 1
  - Problems with Array Segment 4, only ~1/2 of elements powered
- 26 August, Sunday
  - LLTT Leg 2
  - Problems with Array Segment 4, only ~1/2 of elements powered
- 27 August, Monday
  - Ran 4 AEL legs to repeat runs for which data was corrupted and to acquire additional data for element localization
  - LLTT Leg 4
- 28 August, Tuesday
  - LLTT Leg 1a, modify/repeat portion of original Leg 1 (rather than running LLTT Leg 3) at sponsor's request to acquire additional data at array "end-fire"

During the AEL runs the J15 source was towed along track-lines that were nominally N-S legs starting about 1 km south of the arrays to 1 km north of the arrays. For each leg, the source was towed from South-to-North, with the Gulf Stream current, with the tow ship drifting or making headway very slowly to minimize own ship noise and to keep the source as deep as possible. At the end of each AEL leg, the source was recovered for the transit back south to the start of the next leg.

The AEL transmit waveform consisted of a 1 second, 65-418 Hz LFM pulse with a 4 or 6 second repetition rate. In addition, a low level CW tone, 422 Hz, was transmitted continuously at a source level (SL) ~10 dB below the level of the LFM waveform. The CW tone was processed to determine the Doppler shift seen at each of the array elements in order to compensate the matched filter processing of the LFM waveform. The LFM transmits were synchronized with the GPS PPS (pulse per second) pulse so that the absolute arrival time could be measured at each array element.

Figure 2 shows the own ship tracks for the LLTT runs/legs overlaid on a bathymetry map of the area. Again all legs were begun at the south end of the track and the source was towed to the north, with the current. The ship made headway to maximize the distance traveled while maintaining the source depth at ~30 m.

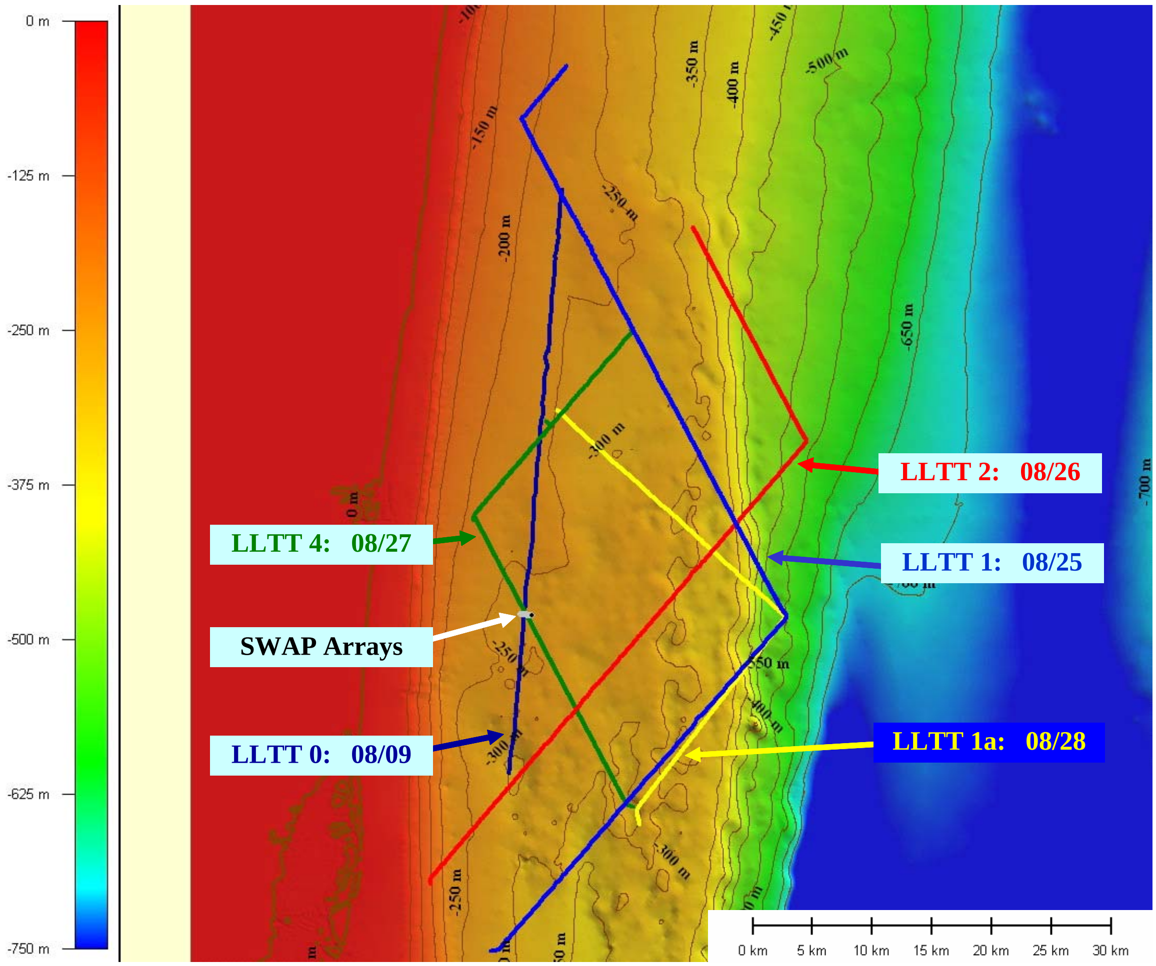

Figure 2. LLTT Runs – Own Ship Tracks overlaid on Bathymetry Chart (Depth in meters)

The LLTT transmit waveform consisted of a 5 sec, 70-420 Hz LFM pulse, no transmission for 10 sec, then several CW tones for 2 min 45 sec. This 3 min long sequence was then repeated for the duration of the run. The CW tones consisted of stronger "marker" tones and weaker "low level" tones as listed below. Following the first LLTT run on 08/25, the SL of the low level tones was reduced by 10 dB from SL1 to SL2.

"Marker" CW Tones		"Low Level" CW Tones		
Frequency	SL	Frequency	SL1	SL2
53 Hz	155 dB	57 Hz	145 dB	135 dB
87 Hz	150 dB	91 Hz	140 dB	130 dB
137 Hz	150 dB	141 Hz	140 dB	130 dB
243 Hz	145 dB	247 Hz	135 dB	125 dB
385 Hz	145 dB	389 Hz	135 dB	125 dB

RESULTS

The data from the AEL runs was processed to determine the element locations relative to each other as well as in absolute latitude/longitude coordinates. The array element locations are shown in Fig. 3 and have been provided to the sponsor and interested researchers as a table giving the location and depth of each of the elements. Details of the AEL processing and the tabulated element locations will be included in the final report (in preparation).

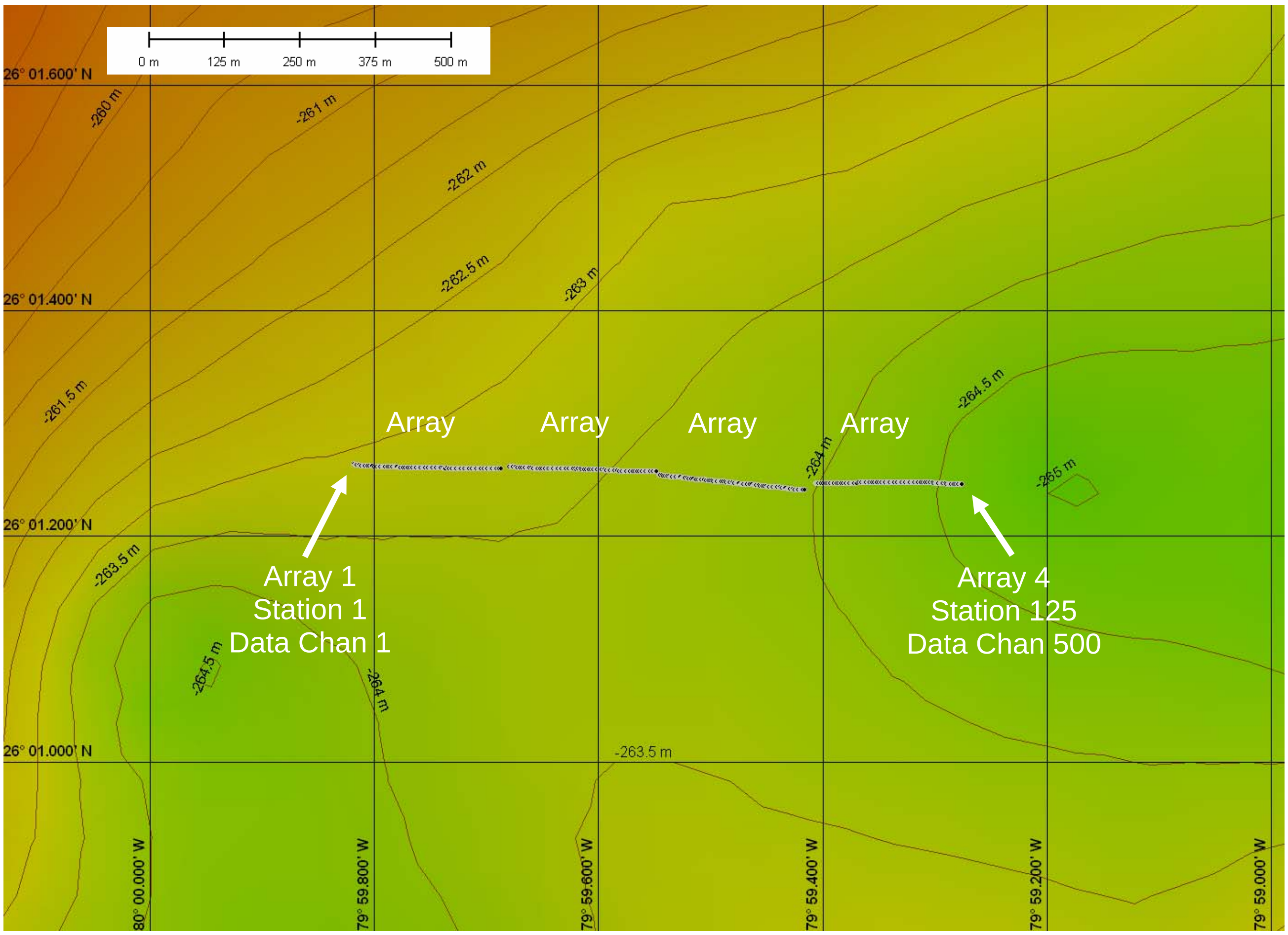

Figure 3. Display of Array Element Locations and Local Bathymetry with Latitude/Longitude Grid

Preliminary analysis results for LLTT Leg 0 (2007-08-09) are shown in Fig. 4-6. Fig. 4 shows a Lofargram plot of the received intensity as a function of frequency (x-axis) and range (y-axis). The narrowband processing formed a track beam using the elements of Array Segment 3 based on the known location of the tow ship/projector as a function of time. Each scan line in the Lofargram is computed using a 20 second data window. Fig. 5 shows Lofargram windows expanded about the transmit frequencies, indicated by the arrows along the frequency axis.

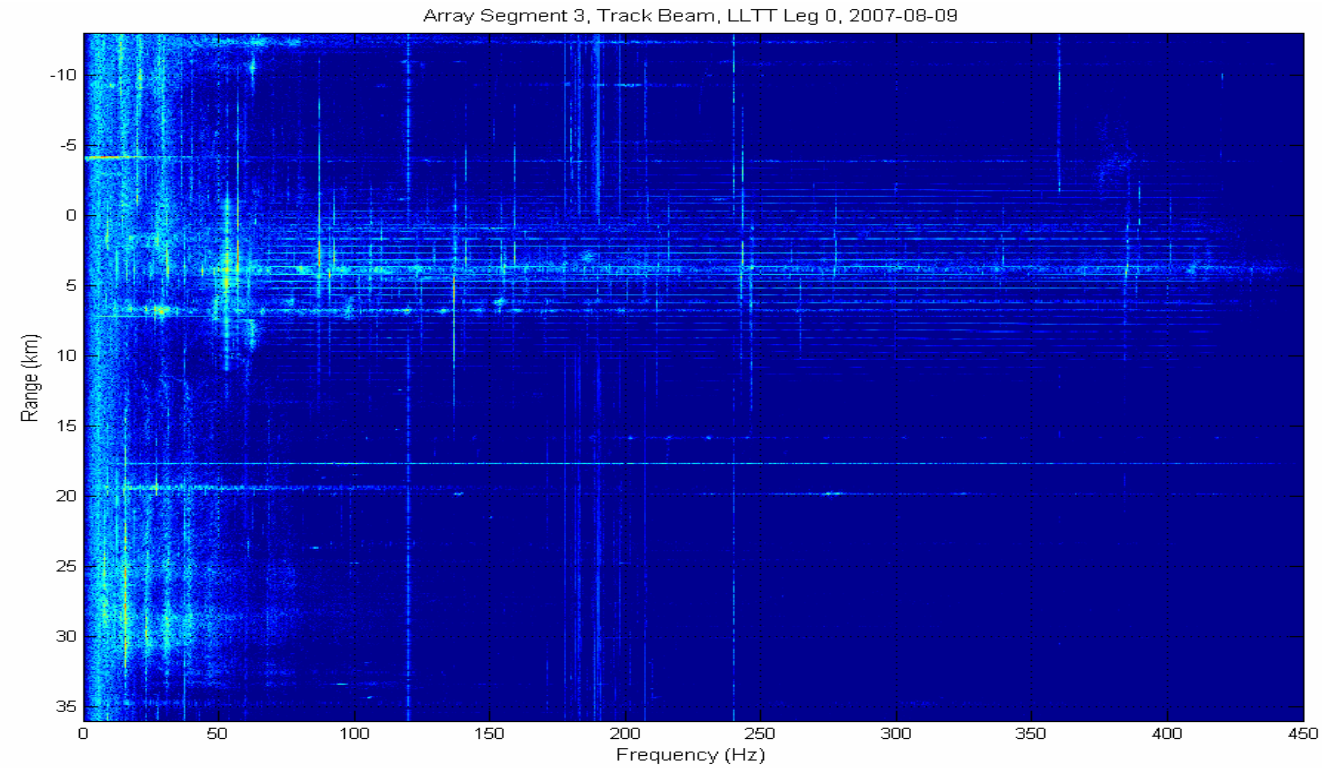

Figure 4. Lofargram for Track Beam formed using Array Segment 3 for LLTT Leg 0 [Waterfall display of received intensity as a function of range (y) and frequency (x).]

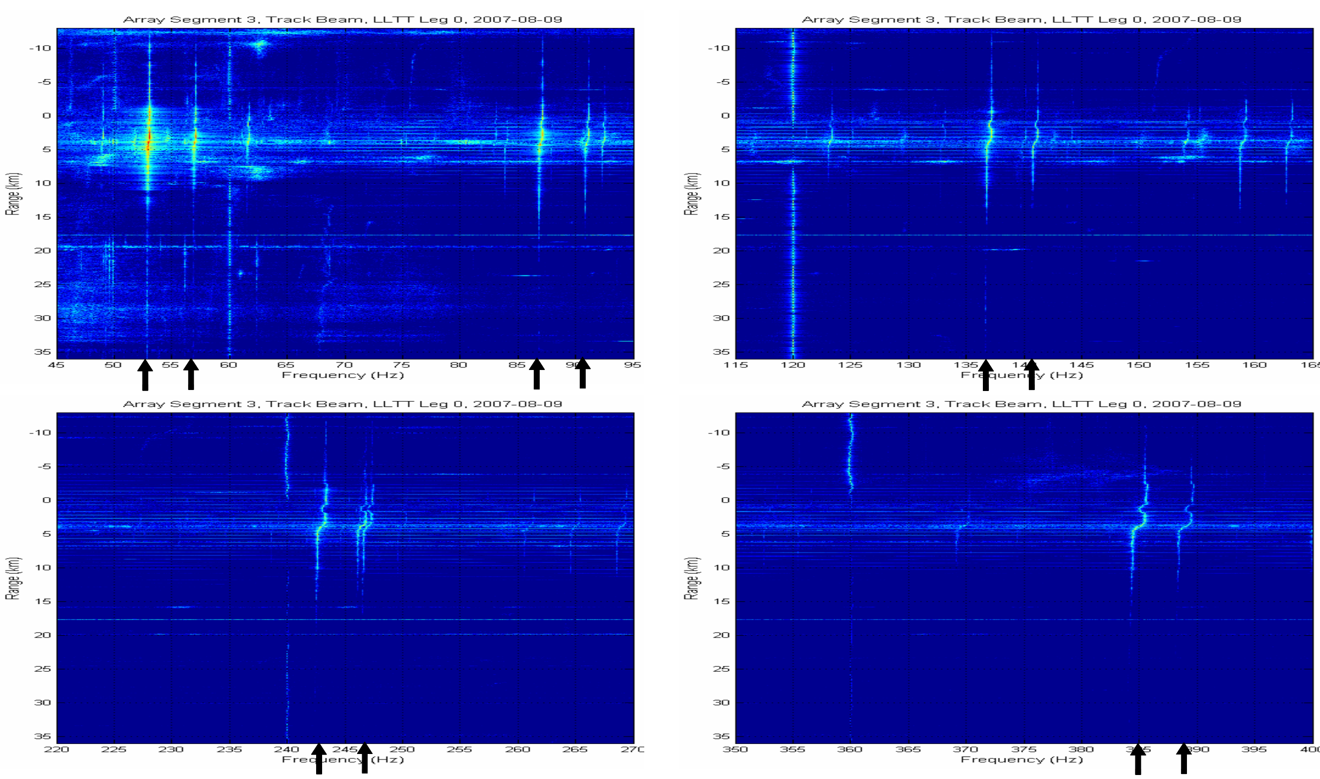

Figure 5. Expanded Lofargram windows for data shown in Fig. 4. Arrows at bottom of the expanded Lofargram windows indicate the LLTT transmit frequencies.

Fig. 6 shows the estimated propagation loss (transmission loss - TL) for the five marker tones as a function of range from the array. Processing consisted of forming a track beam using Array Segment 3, spectral estimates were computed using a 20 second data window and computing the loss based on known source level and element sensitivity. The TL is seen to increase very rapidly with range, between 20 dB and 40 dB in 10 km. It should be noted that the source depth, ~30 m, was relatively shallow with respect to the sound speed gradient.

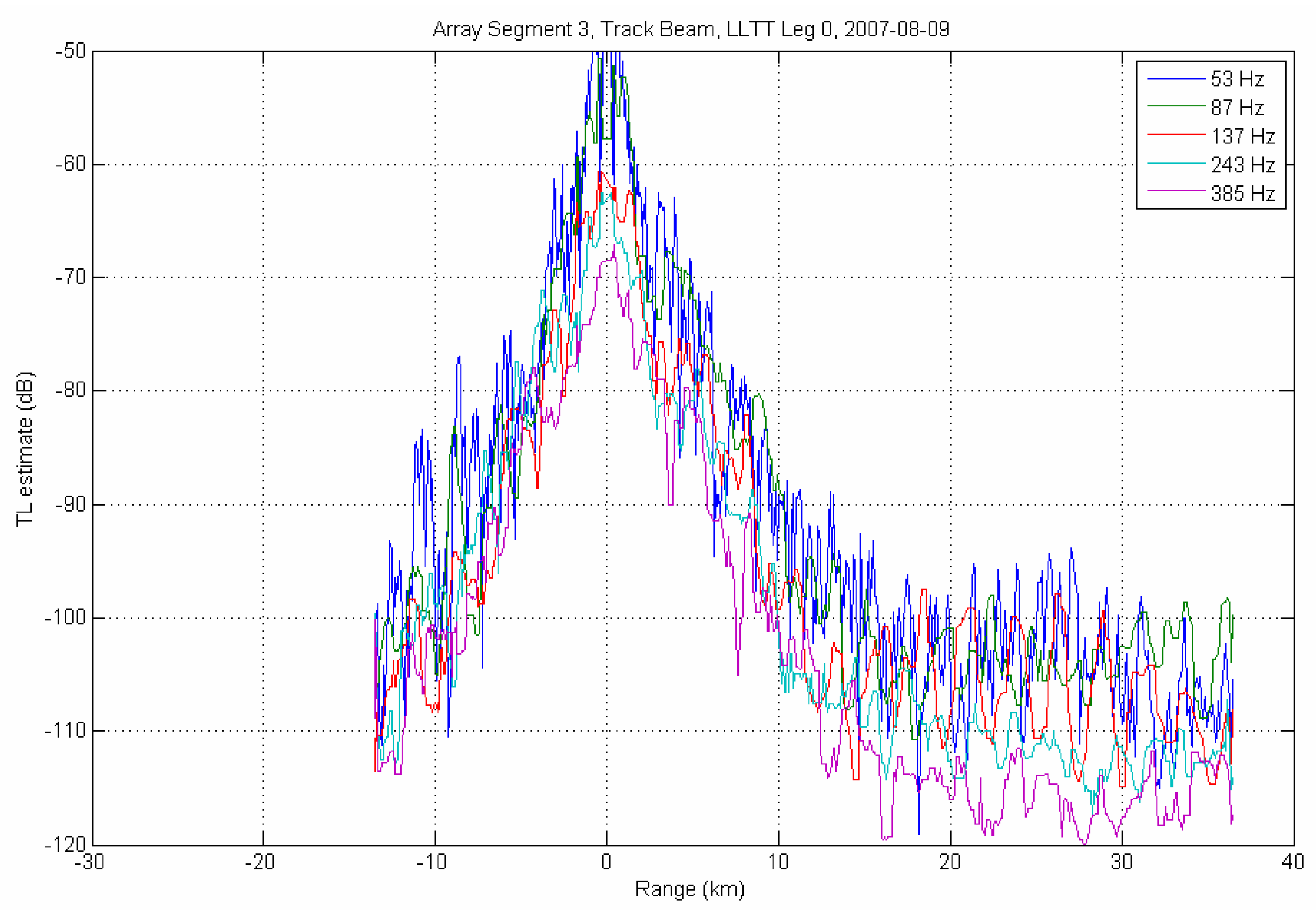

Figure 6. Estimated TL (dB) vs. Range (km) for the Marker tones from LLTT Leg 0

IMPACT/APPLICATIONS

The task will support the development of improved algorithms for passive sonar beamforming, detection and localization in relatively shallow water, high traffic conditions.

RELATED PROJECTS

Efforts under this project are being coordinated with the other projects funded under the Shallow Water Array Performance (SWAP) program.

REFERENCES

[1] Array Element Localization Sea Test Plan, 20 July 2007.
[2] Low Level Tow Test Sea Test Plan, 15 August 2007.